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LTCC based chip for monitoring in biological applications

M. J. Czok^{*}, R. J. Tadaszak, L. J. Golonka*Wrocław University of Technology, Faculty of Microsystem Electronics and Photonics,
Janiszewskiego 11/17, 50-372 Wrocław, Poland*

Abstract

The paper describes technology of the LTCC (Low Temperature Co-fired Ceramics) structure which enables monitoring in biological applications. The results are achieved by light absorbance measurements of liquid sample. Described ceramic structure contains buried microfluidic channels and two co-fired glass windows as well. The signal from three LEDs (Light Emitting Diode) – red, green and blue – can be used in the absorbance measurements. These three elements are connected through the light guide switch and a polymer optical fiber. Thanks to that it is possible to switch stimulation wavelength in wide range of visible spectrum. Optical properties of the fabricated microfluidic LTCC system is investigated mostly with several concentrations of potassium permanganate in water solution.

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Keywords: LTCC; microfluidic; light absorbance; light guide switch

1. Introduction

The LTCC technology can be applied for construction of miniature analytical system. The LTCC multilayer module is composed of dielectric tapes on which different thick films are deposited forming electronic passive components [1]. The LTCC chip can contain buried microfluidic channels and sensors [2]. These allow performing a wide range of analyses. Light absorbance analysis is one of them. Hermetic combination of glass plates and LTCC for optical measurements is a novelty. In addition use of light guide switch (Fig. 1) enables a wide range of visible spectrum analysis. As a result the manual change of light source is eliminated.

^{*} Corresponding author. Tel.: +48 71-355-48-22; fax: +48 71-328-35-04.

E-mail address: mateusz.czok@pwr.wroc.pl.



Fig. 1. (a) Light guide switch; (b) Assembled light guide switch

The ceramic microfluidic system for monitoring in biological applications was designed and manufactured. Windows integration with the ceramic material allowed making both stimulations and measurement directly in the channel.

The LTCC chip and the light guide switch were investigated with distilled water and five concentrations of KMnO_4 solution in distilled water (60-300 μM). The intensity of the non-absorbed light was measured with the TAOS chip. Moreover the reliability of the LTCC system was examined.

2. Device fabrication

The LTCC based chip for monitoring in biological applications was fabricated using LTCC technology. The section of a microfluidic chip is presented in Fig. 2 (a). The one centimeter long absorption region, optical fiber and photodetector chambers are the main parts of the device.

The LTCC microfluidic chip was made of over a dozen DuPont™ 951 LTCC green tapes. Each of them was 254 μm thick. Patterning of green tapes was performed with the laser system (Aurel NAVS 30). After manufacturing of channels, chambers and registration holes, all ceramic layers were stacked together in the appropriate order and laminated in an isostatic press. The lamination process was modified to avoid channels and chambers deformation. The whole LTCC structure with assembled glass plates was co-fired in a box furnace at a recommended firing profile with a peak temperature at 850 $^{\circ}\text{C}$. The LTCC based chip for monitoring in biological applications is presented in Fig. 2 (b).

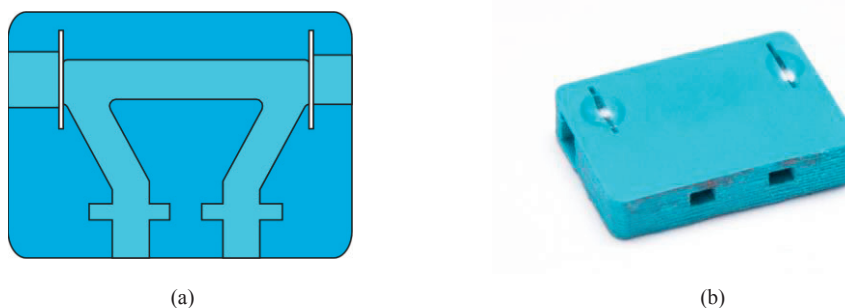


Fig. 2. (a) Section of a microfluidic chip; (b) Manufactured LTCC device

Four layers of DP 951 LTCC tape were used to manufacture ceramic substrates for a light detector and the light guide switch with three light sources. Picture of the co-fired substrate is presented in Fig. 3 (a).

After lamination and burning, three light emitting diodes (LED) and passive electronic components were soldered to the substrate. The light from LEDs is coupled by light guide switch into one optical fiber and transferred to the absorption region in the LTCC chip. The photodetector (TAOS, TCS 3414CS) was mounted on the ceramic substrate with flip chip method using a proper solder reflow profile. The picture of assembled component is presented in Fig. 3 (b).

Three different Optoflash light emitting diodes (red, green and blue) were used as a light source. The red one has a peak wavelength at 624 nm, the green one at 515 nm and the blue one at 470 nm.

As a light detector the TAOS chip was used. It is a small device including an 8×2 array of filtered photodiodes, analog-to-digital converters and control functions. [3].

An electronic system for communication between the TAOS chip and the computer application was designed and manufactured. It is possible to set easily the conversion parameters and luminance of the light source with the computer program. Moreover the program enables automatic data acquisition.

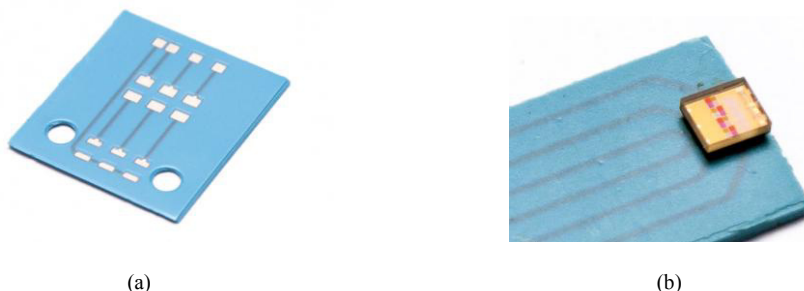


Fig. 3. (a) Light guide switch and LEDs substrate; (b) Flip chip mounted photodetector

3. Measurements

At first the TAOS chip response for light sources of different wavelengths was examined. Measurements were carried out for each LED separately and combinations of two or three LEDs. Experiments were performed for two mediums in the absorption region: air and water. Utilize of the light guide switch made it possible to change the incident light very fast. Such switching method enables fast and versatile diagnoses. Measurements results are presented in Fig. 4 (a) and (b). As can be observed measurements stability was very high. Due to smaller refractions of light at the medium interfaces higher signal levels in water are observed. Despite the lower signal response value for the red diode, other components presence is the lowest. Thus, differences between signal levels are similar. Blue and green components can be well observed for green and blue incident light respectively.

Properties of the ceramic microfluidic chip were determined. For that reason absorbance measurements of several KMnO_4 concentrations were performed. Light absorbance measurements are used in microbiology e.g. for bacteria growth monitoring [4].

Five concentrations of potassium permanganate solution in water in the range from 60 to 300 μM were prepared and tested. The absorbance measurements were carried out in five minutes intervals for each solution. Between measurements cycles the microfluidic chip was purged with distilled water. The intensity of the non-absorbed light was measured with use of the TAOS chip. Measured light intensity was proportional to the concentrations of the test solutions.

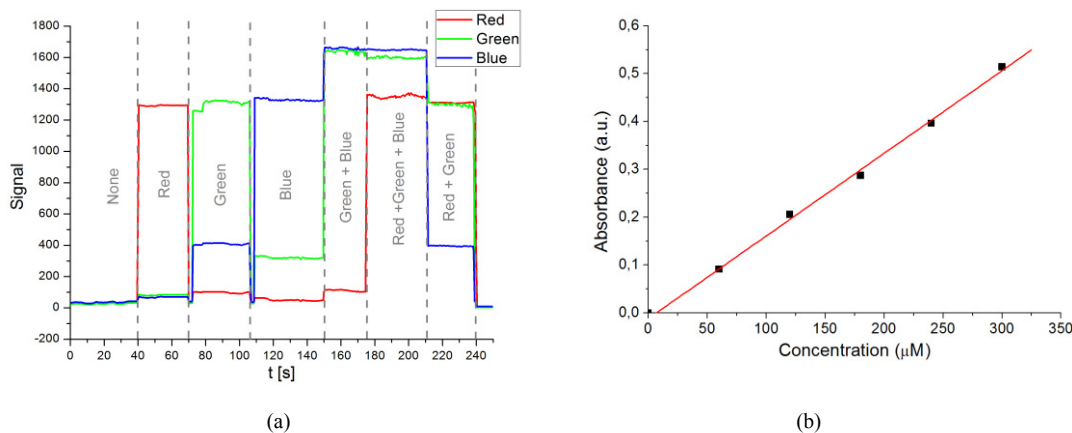


Fig. 4. (a) Measurements in air; (b) Calibration curve

According to the Beer-Lambert's law it was possible to determine the absorbance magnitude of the KMnO_4 concentration in water. The calibration curve of the LTCC based chip for monitoring in biological applications is presented in Fig. 4 (b).

4. Summary

The LTCC based chip for monitoring in biological applications was designed and manufactured. Moreover, use of light guide switch for fast light source change was presented.

Performance of the fabricated ceramic device was investigated using solution concentrations of potassium permanganate in the range from 60 to 300 μM . Measured light absorbance was proportional to the concentration of KMnO_4 in water.

Smaller refractions of light at the medium interfaces caused higher signal levels in water. Despite the lower signal response value for the red diode, blue and green components level was the lowest.

The manufactured LTCC microfluidic chip can be used for fast and versatile diagnoses e.g. light absorbance measurements.

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